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VIII. Report of Thomas Telford, Esq. on the effects which will be produced on the river thames by the rebuilding of London Bridge

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bable that they have not been formed by crystallization in cooling from a state of fusion, but have received their successive increments by reduction of the oxide dissolved in the slag around them: a mode of formation to which we must have recourse for conceiving rightly the formation in nature of many other metallic crystals.

Since the date of this communication, the liberality of Mr. Anthony Hill, of Merthyr Tydvil, has supplied me with a larger quantity of the slag which formed the subject of my first experiments, and has enabled me to determine the specific gravity of metallic titanium to be 5·3. For this purpose, the vitreous part was fused with a mixture of borax and subcarbonate of soda in about equal quantities, and was then dissolved in muriatic acid, which also removed a quantity of metallic iron, and left the titanium freed from extraneous matter. Though great part of what was thus obtained from the interior of the slag was in a pulverulent state, the quantity, which amounted to 32 grains, and displaced 6·04 of water, was sufficient to preclude any considerable error.

I have moreover learned that metallic cubes, similar to those which I have above described and examined, were more than 20 years since observed in a slag at the Clyde iron-works in Scotland; that a small quantity has also been met with at the Low Moor iron-works, near Bradford in Yorkshire; and at the Pidding iron-works, near Alfreton in Derbyshire; and that some good specimens have been obtained from Pontypool in Monmouthshire; but it does not appear that any one has ascertained or even suspected the real nature of this singular product.

VIII. *Report of* Thomas Telford, *Esq. on the Effects which will be produced on the River Thames by the Rebuilding of London Bridge.*

IN consequence of the authority given me by the resolution of the Committee for letting the Bridge-House Estates, dated the 7th of March last, I immediately took measures to get an accurate survey made of the river, its banks and appendages. For this purpose I employed two persons experienced in making similar surveys, viz. one for the district from London Bridge to Putney, and the other from Putney to Teddington Lock; and in order to ensure accuracy and proper connexion and uniformity, I caused one of my own assistants, also accustomed to river surveys, to carry levels from London Bridge to Teddington Lock, and I have myself superintended

perintended and occasionally inspected the proceedings: I have also received the tidal observations made at different times at several stations upon the river.

In order to proceed with regularity, I shall adopt the following arrangement in tracing the effects which would be produced to the westward and also to the eastward of London Bridge, if the present edifice, which constitutes a dam of from 1 foot 1 inch to 5 feet 7 inches, or 4 feet 4 inches on an average, were removed, and in its stead a new bridge, with comparatively little obstruction, were substituted:

1st. Observations on the comparative state of high water, founded on the surveys and levels lately taken, and the tidal observations made in 1820, 1822, and 1823; and further, what is likely to take place if London Bridge be removed.

2dly. Similar observations as regards the state of low water.

3dly. As to the effects which the aforesaid changes are likely to produce upon the navigation, bridges, banks, wharfs, shores, and adjacent properties.

First, As to the State of the River at High Water.

It appears from the table of observations of the height of the tides at the several bridges in 1820 and 1822, that the average fall through London Bridge at high water was from 8 to 13 inches; that by those of 1823, since the removal of the water-works, the fall instead of 8 inches is now only from 3 to 4 inches; I think therefore it is fair to conclude that with a still less obstructed waterway there will be little or no fall at high water, and that hereafter high tides in the western parts of the city will even in calm weather be at least on the same level as below bridge. I find that the level of the wharfs below bridge is from 2½ to 4 feet above the Trinity datum, and that those of 2½ feet are occasionally flooded. The average level of the wharfs above bridge is from 1½ to 2 feet above the Trinity datum; and the extraordinary flood of 1821, which rose at Teddington 7 feet, rose at Putney only 2 feet, and at Lambeth 1 foot 11 inches above the said datum. Therefore it appears that there is more reason at present to dread the elevation arising from the tide below bridge, than from floods above; and that the floods of the Thames are not sufficient, in the present state of things, to fill the lagoon or pond above the narrows of the bridge to the height which some of the tides do below, and which, there is reason to believe they also would above, were the channel unobstructed.

But it may be supposed that the quantity of tide coming in at the Nore being given, the additional space provided for it by by opening the upper part of the river will prevent it from rising so high as it now does near the bridge, and that therefore not only is there a probability of no greater elevation occurring there than at present, but that it will, in similar circumstances, be lower below bridge—consequently that no danger can arise above. To this I reply, that when it is high water at the Nore, we have it, within two hours, high water at London Bridge, at the distance of forty miles; so that the high water passes up at the rate of twenty miles per hour: so much more rapidly than any known velocity of the river, that its effects are not to be accounted for by the flowing of the current merely, as may be supposed the case in filling up the pond to Teddington through the arches of London Bridge.

In this last case we have levelled along the banks of the river, and find, after correcting the marks expressing Trinity datum, that the lowest surface of high water is between Putney and Kew; that it rises about one foot to Teddington, and nearly as much at London Docks: but this is liable to considerable variation. The rise in the upper part of the river pond may be easily accounted for by the accumulation of the fresh waters of the river over and above what is tidal water. The fall from London towards Putney seems to show that the tide has not time, through the contracted passage, to fill up the pond above bridge to the lower level.

From London Bridge to Blackwall the high water seems, from the observations, to be level: the quantity of water required to fill up this difference of level is, after all, so small, that with an unobstructed waterway it would evidently make no difference worthy of notice in the level of the tide below bridge, even were it subtracted from the mass that lies between London Bridge and the Nore. Whereas considering the great rapidity with which the lower part of the river is filled by the tide, it is clear that an unobstructed tide would fill up this trifling increase in at least as little time as the present period.

But to render this a matter of calculation: we find the average breadth of tide-water at the Nore to be $3\frac{1}{2}$ miles; at Gravesend half a mile, the distance being 18 miles; which, at 6000 feet per geographical mile, with 15 feet of tide, gives from the Nore to Gravesend 17,000 millions cubic feet of tide-water: at London Bridge, taking the breadth at 1000 feet and 3000 at Gravesend, we have in 24 miles, and with the same depth, 4320 million of cubic feet, or 1-4th additional tide-water. There run at present through London Bridge, between the lowest ebbs and high water of ordinary springs (or 14-feet tides) above bridge, 582 millions cubic feet (582,342,710); and

and if London Bridge be removed, so that there be no material dam at low water, we have also to fill the pond now caused by that dam. This pond is from 4 to 6 feet deep at the bridge, at low water; and we find that the level of low water above bridge meets the bottom of the Thames between Putney and Kew, viz. 10½ miles above bridge: taking this as the head of the pond, the average breadth at 600 feet at low water, the mean depth to be filled at 2 feet, we have an addition of 75 millions of cubic feet, or 1-57th of the quantity of tide-water between London and Gravesend, or only 1-284th of the whole quantity of tide-water within the Nore; therefore the whole water which must pass the New Bridge, to raise the upper river to the level of high water below bridge, is 657 millions, or 1-32d of the entire quantity of tide-water within the Nore below bridge.

It is a well-known fact that the tide in narrow channels with funnel-shaped mouths, or against coasts which oppose its regular course, rises considerably higher than at the places which are situated in retired bays, or under the wake of projecting points: thus the Atlantic tide running up the Channel rises 6 or 7 fathoms against the French coast near St. Malo and Havre; while on the opposite English coast, at Portland and Poole, we have only one fathom rise. In St. George's Channel, the tides at Milford and along the Welsh coast rise four fathoms; on the opposite Irish coast, from Carnsore Point to Wicklow, hardly one fathom. Many similar instances might be given. Again, as to funnel-shaped mouths: the spring-tide at the entrance of Bristol Channel rises 22 to 24 feet; but as that channel contracts in breadth, the velocity and vertical rise increase in proportion so much, that in King Road it rises between 7 and 8 fathoms. Many other similar instances may be shown. As may be perceived by the position of the banks of the Thames' mouth, the flood-tide comes from the N.E. or German sea: at half-past eleven it is high water at Harwich, Kentish Knock, and Margate; the oscillation or rise at springs is from 15 to 16 feet; at twelve it is high water at the Nore; and although the rise there is only 14 feet, yet in the Swale, which is in the direct course of the tide, the rise is 17 to 21 feet at half-past twelve.

The general set of the current running up the Thames forms a branch which at the Nore at noon rises, as we have said, 14 feet; but from thence the funnel-shape produces a gradual increase in the oscillation until we arrive near London: that at Gravesend, at one, the rise is 16 feet; at Woolwich, at three-quarters past one, it is 18 feet; at Deptford, at two o'clock, we have 18¾ feet; but at Billingsgate, at a quarter past

past two o'clock, there is a rise of $17\frac{1}{2}$ feet only. The action of the tide is now affected by the bridges, the regular progress of this wave being checked, and the surface of the high water declines all the way to Putney, where it is high water at a quarter past three o'clock; but from thence again there is a rise of one foot to Teddington, where it is high water at three-quarters past four. Hence observe that from Billingsgate to Teddington the wave passes at the rate of 8 miles per hour only; while below Billingsgate the same wave of high water passes at the rate of 20 miles per hour, or more particularly

	Miles.		Time. Hour.	Minutes.		Miles.
From the Nore to Gravesend	18	in	1	0	is	18 per ho.
Woolwich	15	—	$\frac{3}{4}$	0	—	20
Deptford	$6\frac{1}{2}$	—	$\frac{1}{4}$	0	—	26
Billingsgate	4	—	$\frac{1}{4}$	0	—	16
Swan Stairs, a loss of				10	—	
Putney	7	in		50	—	$8\frac{1}{2}$
Teddington	11	—	$1\frac{1}{2}$	0	—	$7\frac{1}{3}$

It is obvious then that this rapid diminution of the velocity of high water is caused by the narrow at London Bridge, and that, were that obstruction removed, there is every reason to believe the velocity in the upper river would be greatly increased.

It must also be observed that the fall or difference of height between the surfaces above and below bridge at high water must not alone be taken as the proper measure of the obstruction, and used as a datum throughout a calculation, because the fall through the whole tide is much greater. In one very moderate spring-tide, which I observed on the 26th of May last, when the fall at high water was only 5 inches, the fall through most of the preceding part of the tide had been 14 inches.

The high water will therefore go up to the head of the tide-way more speedily, and will rise higher than at present.

Secondly, Of the River at Low Water.

This water must also return with greater velocity, and the removal of the bridge will not only permit the increased head to pass off at the ebb, but likewise that portion which is now retained by the obstruction.

Were the flood tide not to return, and the stream of the river to cease, the bed would exhibit a series of ponds at levels, gradually increasing in elevation as we pass to the westward; of which the first would extend to Battersea Bridge, having a shoal at Westminster Bridge, on which there will be little or

 no

no water, and nearly 2000 yards in length. The second pond, from Battersea to Putney, would be 16 inches higher than the former. At Putney Bridge would be a rise of 17 inches. Above Putney to Mortlake is a shallow channel with small pools; in the deepest passage across the bars there is now less than 3 feet of water. Mortlake is the next pond, two miles in length. Its surface is level with the present low water at London Bridge; but before the construction of that work it would, as its name implies, have been a dead or stagnant lake at low water. The other ponds which are higher than the present low water may be observed in the general section. The depth over the bar is no where less than $2\frac{1}{2}$ feet, or more than 4 feet; but this depth is with some difficulty sufficient at present for navigation to the locks at Teddington.

Were the river water to be run off above bridge, this navigation must cease, unless a new channel be excavated through the shoals: independent of the depression in the lower pond which the New Bridge will permit, a longer time will be given for the ebb to empty the upper reaches, as we may see by inquiring whether the obstruction of London Bridge occasions any remarkable deviation from the progress of the ebb, as we have just found it to do in the case of the flood tide, whereby we form some judgement of the probable result of its removal with respect to the velocity of the ebb stream.

Allowing therefore that the tide at the Nore occupies 6 hours 16 minutes, or the regular half tide, we find that low water proceeds —

	Miles.		Time. Hour.	Minutes.	Miles.
From the Nore to Gravesend	18	in	1	24	13 per ho.
Woolwich	15	—	1	8	
Deptford	$6\frac{1}{2}$	—	0	$37\frac{1}{2}$	$10\frac{2}{3}$
Billingsgate	4	—	0	$22\frac{1}{2}$	10
Old Swan, a loss of				20	
Westminster	2	in	0	$22\frac{1}{2}$	5
Putney	$5\frac{1}{2}$	—	1	34	$3\frac{1}{2}$
Teddington	11	—	3	20	$3\frac{1}{3}$

which exhibits the same rapid changes of velocity caused by the bridge as in the case of flood.

Were the bridge removed, therefore, it is evident that the velocity of ebb above bridge would materially increase, the time of low water be earlier than at present, the drainage of the upper ponds more complete, and the navigation which is now practicable up to Teddington would cease too early near that place.

Thirdly, Effects to be produced.

And lastly, from the foregoing statement of facts it has been shown

shown that the removal of London Bridge will admit a greater body of water to flow up the river to the westward, and with a greater velocity, which together will considerably increase the momentum; and it is equally certain that the same cause will operate in the ebbing tide, and leave the bed of the river nearly dry for several hours in the latter part of the ebb. This will in part be remedied by the increased velocity and momentum scouring away the mud, sand, and small gravel, so as to deepen the bed; but this cannot take place where the matter has more consistence, and to obtain the same depth as at present at low water would require excavation to a very great extent, probably to incur an expense of 40,000*l*.

But this lowering of the bed, if accomplished either by the tide scour or artificial excavation, would seriously affect the foundations of some of the other bridges. The piers of Westminster Bridge stand upon gravel without having piles under them, and several are now not more than 3 feet under the present surface of the river bed, the matter of which I proved to be sand and gravel. By the plate of the geometrical elevation and plan of Blackfriars' Bridge, published from drawings by Mr. Baldwin, the bottom of the platforms is not more than about 5 feet below the present bed of the river: these piers have, it is true, piles of about 10 feet in length under them, but if the bed were lowered they would require to be protected. Some of the piers of Waterloo Bridge have their platforms laid only at about 6 feet 4 inches under the line of the present low-water mark. Respecting the bridges between Westminster and Teddington, which stand partly on stone piers and partly upon wooden piles, I have not hitherto been able to obtain any accurate information; but it is clear that the lowering of the bed of the river would in some measure affect them.

With regard to wharfs and houses built on the banks of the river, the lowering of the surface of low water, and extending the time of that depression, would afford an opportunity of a greater drainage from the adjacent soil upon which buildings are erected, and may have the effect of causing settlements: if no excavation takes place in the shores adjacent to the wharfs, the barges, &c. will be longer prevented from approaching to or departing from them: if an excavation does take place, there will be some risk of the walls being undermined. These observations apply to the whole river as far as Teddington.

Besides these consequences from lowering the bed of the river, others will unavoidably follow from the tide above London Bridge rising higher than it does at present. Many of the wharfs by the sides of the river are not more than from $1\frac{1}{2}$ to 2 feet above Trinity Datum, and are not unfrequently

 overflowed,

overflowed, partly by land floods, but chiefly by high tides, which rise above a foot higher below bridge than they do at present above bridge: the evil will therefore be proportionably increased both in degree and frequency. But besides the common operations of land floods and tides in calm weather, all the river above bridge will, when the dam is removed, be further exposed to the influx of heavier waves driven from the Nore, with storms from the northward, which have hitherto been checked by the almost solid mass of the upper part of London Bridge. These observations apply to all the banks and low grounds on each side of the river from Westminster to Teddington, and which are very extensive.

Instances of such influx and rising of the tide have been already mentioned, and another has come to my knowledge while engaged in the present survey. At the Cashen river in Kerry, which falls into the sea near the mouth of the Shannon, a bar has been lately cut across to make a more direct navigation: the upper river has thereby been lowered two or three feet at low water, and at high water raised so as to overflow the marshes more than before; and the direct stream is now cutting a channel through the sandy shoals above the bar. This information I received from the able engineer (Mr. Nimmo) who advised the measure.

The Effects Eastward of the Bridge.—No longitudinal or cross sections having been taken to the eastward of the bridge, I have no accurate knowledge of the state of the river bed, and can therefore only observe generally, that my investigations have led me to the conclusion that more water will pass with a greater velocity in every part of the river; but as the difference will diminish as the section increases, the effects will of course disappear in the lower parts of the river. When operations do take place, they will scour and deepen the river, where the matter is alluvial and loose.

24, Abingdon-street, Westminster, June 11, 1823. THOMAS TELFORD.

IX. *Observations on the Project of taking down and rebuilding London Bridge* *.

IT is a matter certainly of great interest to men of science, to know what effect the removal of a dam producing a fall of water westward at high water sometimes of two feet, and eastward at low water sometimes of nine feet, from a great river like the Thames, would have westward and eastward of that dam in respect to the bed and shores of such a river; and

* From the Quarterly Journal of Science, &c. No. xxx.

whether